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(54) Homogeneous low melting point copper based alloys.

(57) A copper based low melting point metal alloy composition consists essentially of about 5 to 52 atom percent nickel, about 2 to 10 atom percent tin, about 10 to 15 atom percent phosphorus and the balance essentially copper and incidental impurities. The composition is such that the total of copper, nickel and tin ranges from about 85 to 90 atom percent.

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DESCRIPTION

HOMOGENEOUS LOW MELTING POINT COPPER BASED ALLOYS

CROSS-REFERENCE UNDER RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Patent Application Serial No. 420,549, filed September 20, 1982.

1. Field of the Invention

This invention relates to copper based metal alloys and more particularly to a homogeneous, ductile brazing material useful for brazing metal articles such as those composed of copper and copper alloys.

2. Description of the Prior Art

Brazing is a process of joining metal parts, often of dissimilar composition, to each other. Typically, a filler metal that has a melting point lower than that of the metal parts to be joined together is interposed between the metal parts to form an assembly. The assembly is then heated to a temperature sufficient to melt the filler metal. Upon cooling, a strong, leak-tight joint is formed. Filler metals used are commonly in powder, wire or foil form, depending on the type of application.

Foil form provides the advantage of preplacing the filler metal in the joint area, thus permitting brazing of complex shapes with minimum rejection.

The brazing alloys suitable for use with copper and copp r alloys, designated AWS BAg, are well known compositions. These alloys contain substantial amounts of th precious metal silver (19 to 86 weight

percent) and hence ar xpensive. Most of the AWS Bag compositions are fabricated to a foil form through a lengthy sequence of rolling and annealing steps, incurring substantial processing cost.

Ductile glassy metal alloys have been disclosed in U.S. Patent No. 3,856,513, issued December 24, 1974 to H.S. Chen, et al. These alloys include compositions having the formula T_iX_j, where T is a least one transition metal and X is an element selected from the group consisting of phosphorus, boron, carbon, aluminum, silicon, tin, germanium, indium, beryllium and antimony, "i" ranges from about 70 to about 87 atom percent and "j" ranges from about 13 to 30 atom percent. Such materials are conveniently prepared in powder, wire or foil form by rapid quenching from the melt using processing techniques that are now well-known in he art. However, no liquid-quenched glassy metal alloys of the family T_iX_j described above, containing copper as the principal transition metal have been reported. Chen, et al. report only one copper containing composition (e.g., $Pd_{77.5}Cu_6Si_{16.5}$) in U.S. Patent No. 3,856,513. H. Suto and H. Ishikawa, Trans. Japan Inst. of Metals, V. 17, 1976, p. 596, report fabrication of glassy Cu-Si by vapor deposition.

There remains a need in the art for a homogeneous brazing material for joining copper and copper alloys that is free of precious metals and is preferably in foil, powder or wire form.

SUMMARY OF THE INVENTION

The present invention provides a low melting point copper based metal alloy composition. Generally stated, the composition consists essentially of about 5 to 52 atom percent nickel, about 2 to 10 atom percent Sn, about 10 to 15 atom percent P, and the balance essentially Cu and incid ntal impurities. The composition is such that th total of Cu, Ni and Sn ranges from about 85 to 90 atom percent. Preferably, the metal alloy composition has at least partially glassy

structur .

In addition, th invention provides a homog n ous, ductile brazing f il having a composition consisting essentially of 5 to 52 atom percent nickel, 2 to 10 atom percent tin and 10 to 15 atom percent phosphorus, the balance being copper and incidental impurities, with the total of copper, nickel and tin ranging from about 85 to 90 atom percent. Preferably, the brazing foil of this invention is at least partially glassy and consists essentially of 5 to 15 atom percent nickel, 2 to 5 atom percent tin and 10 to 15 atom percent phosphorus, the balance being copper and incidental impurities.

The addition of Ni increases joint strength, while the addition of Sn improves joint ductility and depresses the melting point of Cu. Phosphorus acts as a temperature depressant and, by forming a compound, Cu_3P, with the Cu constituent provides a self-fluxing characteristic to the filler metal.

The homogeneous brazing foil of the invention is fabricated by a process which comprises forming a melt of the composition and quenching the melt on a rotating quench wheel at a rate of at least about 10^5 °C/sec.

Further, there is provided in accordance with the invention, an improved process for joining two or more metal parts by brazing. The process comprises:

(a) interposing a filler metal between the metal parts to form an assembly, the filler metal having a melting temperature less than that of any of the metal parts;

(b) heating the assembly to at least the melting temperature of the filler metal; and

(c) cooling the assembly.

The improvement comprises employing, as the filler metal, a homogeneous, copper bas d foil that has the composition given above.

The filler metal foil is easily fabricable as homog n ous, ductile ribbon, which is us ful for brazing

as cast. Advantageously, the copp r based metal foil can be stamped into compl x shapes to provid braze preforms.

Advantageously, the homogeneous, ductile brazing foil of the invention can be placed inside the joint prior to the brazing operation. Use of the homogeneous, ductile copper based foil provided by this invention also permits brazing to be accomplished by processes such as dip brazing in molten salts, which are not readily accomplished with powder or rod-type fillers.

DETAILED DESCRIPTION OF THE INVENTION

Glassy metal alloys are formed by cooling a melt of the desired composition at a rate of at least about 10^5°C/sec. A variety of rapid quenching techniques, well known to the glassy metal alloy art, are available for producing glassy metal powders, wires, ribbon and sheet. Typically, a particular composition is selected, powders or granules of the requisite elements in the desired portions are melted and homogenized, and the molten alloy is rapidly quenched on a chill surface, such as a rapidly rotating cylinder, or in a suitable fluid medium, such as water.

Copper based brazing alloys have been fabricated by processes such as those described above.

In any brazing process, the brazing material must have a melting point that will be sufficiently high to provide strength to meet service requirements of the metal parts brazed together. However, the melting point must not be so high as to make difficult the brazing operation. Further, the filler material must be compatible, both chemically and metallurgically, with the materials being brazed. The brazing material must be more noble than the metals being brazed to avoid corrosion. Ideally, the brazing material must be in ductile foil form so that complex shapes may be stamped therefrom. Finally, the brazing foil should be homogeneous, that is, contain no binders or other materials that would otherwise form voids or contaminating resi-

idues during brazing.

In accordance with the invention, a homogeneous, ductile brazing material in foil form is provided. The brazing foil includes compositions ranging from about 5 to 52 atom percent Ni, about 2 to 10 atom percent Sn, about 10 to 15 atom percent P, and the balance essentially Cu and incidental impurities.

These compositions are compatible with copper and copper-based alloys and are particularly suited for joining these materials.

By homogeneous is meant that the foil, as produced, is of substantially uniform composition in all dimensions. By ductile is meant that foil can be bent to a round radius as small as ten times the foil thickness without fracture.

Examples of brazing alloy compositions within the scope of the invention are set forth in Table I.

TABLE I

Sample No.		Composition Cu	Ni	Sn	P
1	atom %	73	10	2	15
	wt %	78.25	9.90	4.00	7.84
2	atom %	68	15	2	15
	wt %	73.19	14.92	4.02	7.87
3	atom %	71	10	5	14
	wt %	73.65	9.58	9.69	7.08
4	atom %	68	10	10	12
	wt %	66.82	9.08	18.35	5.75
5	atom %	64	16	9	11
	wt %	63.39	14.64	16.65	5.31
6	atom %	66	15	5	14
	wt %	68.73	14.43	9.73	7.11
7	atom %	58	20	10	12
	wt %	57.42	18.30	18.49	5.79
8	atom %	28	52	10	10
	wt %	28.11	48.24	18.75	4.89
9	atom %	61	20	5	14
	wt %	63.78	19.32	9.77	7.14
10	atom %	63	15	10	12
	wt %	62.14	13.67	18.42	5.77
11	atom %	40	40	10	10
	wt %	39.80	36.77	18.58	4.85
12	atom %	63	20	2	15
	wt %	68.09	19.97	4.04	7.90
13	atom %	75.5	6	5	14
	wt %	77.6	5.7	9.7	7.0
14	atom %	80	6	8	6
	wt %	77.6	6.3	4.2	11.9
15	atom %	76	6	12	6
	wt %	75.1	6.4	6.3	12.2
16	atom %	82	6	4	8
	wt %	76.6	6.1	2.0	15.3
17	atom %	78	6	8	8
	wt %	74.1	6.2	4.1	15.6

Within the broad range disclosed abov , ther is a preferred composition rang that is compatible with and permits brazing of copper and a wide range of copper alloys under a wide range of atmospheric conditions. Such preferred composition range permits copper and copper alloys to be joined under substantially all brazing conditions. The preferred compositions contain from about 5 to 15 atom percent Ni, from about 2 to 5 atom percent Sn, from about 10-15 atom percent P, the balance being Cu and incidental impurities.

Further, in accordance with the invention, an improved process for joining two or more metal parts is disclosed. The process comprises:

(a) interposing a filler metal between the metal parts to form an assembly, the filler metal having a melting temperature less than that of any of the metal parts;

(b) heating the assembly to at least the melting temperature of the filler metal; and

(c) cooling the assembly.

The improvement comprises employing, as the filler metal, at least one homogeneous, copper based foil having a composition within the ranges given above.

The brazing foils of the invention are prepared from the melt in the same manner as glassy metal foils. Under these quenching conditions, a metastable, homogeneous, ductile material is obtained. The metastable material may be glassy, in which case there is no long range order. X-ray diffraction patterns of glassy metal alloys show only a diffuse halo, similar to that observed for inorganic oxide glasses. Such glassy alloys should be at least 50% glassy to be sufficiently ductile to permit subsequent handling, such as stamping complex shapes from ribbons of the alloys. Preferably, the glassy metal alloys should be totally glassy, to attain superior ductility.

The metastable phase may also be a solid solution of the constituent elements. In the case of

the alloys of the invention, such metastable, solid solution phases are not ordinarily produced under conventional processing techniques employed in the art of fabricating crystalline alloys. X-ray diffraction patterns of the solid solution alloys show the sharp diffraction peaks characteristic of crystalline alloys, with some broadening of the peaks due to desired fine-grained size of crystallites. Such metastable materials may also be ductile when produced under the conditions described above.

The brazing material of the invention is advantageously produced in foil (or ribbon) form, and may be used in brazing applications as cast, whether the material is glassy or a solid solution. Alternatively, foils of glassy metal alloys may be heat treated to obtain a crystalline phase, preferably fine-grained, in order to promote longer die life when stamping of complex shapes is contemplated.

Foils as produced by the processing described above typically are about 0.0010 to 0.0025 inch (0.00254-0.00635 cm) thick, which is also the desired spacing between bodies being brazed. Such spacing maximizes the strength of the braze joint. Thinner foils stacked to form greater thicknesses may also be employed. Further, no fluxes are required during brazing, and no binders are present in the foil. Thus, formation of voids and contaminating residues is eliminated. Consequently, the ductile brazing ribbons of the invention provide both ease of brazing, by eliminating the need for spacers, and minimal post-brazing treatment.

The brazing foils of the invention are also superior to various powder brazes of the same composition in providing good braze joints. This is probably due to the ability to apply the brazing foil where the braze is required, rather than depending on capillarity to transport braze filler metal from the edge of surfaces to be brazed.

EXAMPLE 1

Ribbons about 2.5 to 6.5 mm (about 0.10 to 0.25 inch) wide and about 25 to 60 m about (about 0.0010 to 0.0025 inch) thick were formed by squirting a melt of the particular composition by overpressure of argon onto a rapidly rotating copper chill wheel (surface speed about 914.4 to 1828.8m/min). Metastable, homogeneous alloy ribbons having at least partially glassy atomic structure were produced. The compositions of the ribbons are set forth in Table I.

EXAMPLE 2

The liquidus and solidus temperatures, T_L and T_S, of selected ribbons in Table I were determined by Differential Thermal Analysis (DTA) technique. These temperatures are set forth in Table II.

TABLE II

Sample No.	Composition	T_L °C (°F)	T_S °C (°F)
1 atom %	$Cu_{73}Ni_{10}Sn_2P_{15}$	645 (1193)	610 (1130)
2 atom %	$Cu_{68}Ni_{15}Sn_2P_{15}$	645 (1193)	610 (1130)
3 atom %	$Cu_{71}Ni_{10}Sn_5P_{14}$	635 (1175)	595 (1103)
4 atom %	$Cu_{68}Ni_{10}Sn_{10}P_{12}$	638 (1180)	508 (946)
5 atom %	$Cu_{64}Ni_{16}Sn_9P_{11}$	750 (1382)	510 (950)
6 atom %	$Cu_{66}Ni_{15}Sn_5P_{14}$	730 (1346)	590 (1094)
7 atom %	$Cu_{58}Ni_{20}Sn_{10}P_{12}$	720 (1328)	505 (941)
11 atom %	$Cu_{40}Ni_{40}Sn_{10}P_{10}$	863 (1588)	825 (1517)
13 atom %	$Cu_{75}Ni_6Sn_5P_{14}$	643 (1190)	591 (1096)
14 atom %	$Cu_{77.6}Ni_{6.3}Sn_{4.2}P_{11.9}$	628 (1162)	-
15 atom %	$Cu_{75.1}Ni_6Sn_{6.3}P_{12.2}$	618 (1144)	-
16 atom %	$Cu_{76.6}Ni_{6.1}Sn_{2.0}P_{15.3}$	660 (1220)	-
17 atom %	$Cu_{74.1}Ni_{6.2}Sn_{4.1}P_{15.6}$	640 (1184)	-

EXAMPLE 3

Lap sh ar test sp cimens were prepared according to AWS C 3.2 "Standard Method for Evaluating the Strength of Brazed Joints". Copper sheet, 3.175 mm (0.125") thick was used as the base metal. Ribbons of selected compositions having dimensions of about 25.4 m to 38.1 m (0.001" to 0.0015") thick and about 6.35 mm (0.25") wide were used as the filler metal. Brazed joints were of the lap type with the lap dimension carefully controlled to 6.35 mm (0.25") and 12.7 mm (0.5"). Specimens were then degreased in acetone and rinsed with alcohol. The mating surfaces of the blanks were fluxed using boric acid. Lap joints containing selected brazing ribbons of the invention were then assembled by laying ribbons side by side to cover the entire length of the lap joint. Specimens were then clamped and torch brazed using oxyacetylene flame with 8 psi oxygen and 8 psi acetylene pressure. Brazed specimens were then air cooled to room temperature and the flux residue was removed by wire brushing.

For comparative purposes identical joints were prepared using 5.4 m (0.001") thick BCuP-5 foil and (0.062") dia BAg-1 and BAg-2 rod.

The compositions and brazing temperature ranges of these filler metals are given in Table IIIA and Table IIIB respectively. When the applied filler metal was in rod form (BAg-1 and BAg-2 alloys), a clearance of 38.1 m (0.0015") was kept between the mating surfaces of the blanks by placing stainless steel spacers at the two edges. The assembly was then heated to the brazing temperature range of these alloys and the filler metal was applied to one side only. The molten filler metal was then drawn by capillary action and covered the entire mating surfaces.

TABLE IIIA

Alloy		Ag	Cu	P	Zn	Cd
BCuP-5	atom %	8.92	80.73	10.35	-	-
	wt%	15	80	5	-	-
BAg-1	atom %	37.53	21.24	-	22.02	19.21
	wt%	45	15	-	16	24
BAg-2	atom %	26.71	33.67	-	26.44	13.18
	wt%	35	26	-	21	18

TABLE IIIB

Alloy	Temp °C (°F)
BCuP-5	704-816 (1300-1500)
BAg-1	618-760 (1145-1400)
BAg-2	635-760 (1175-1400)

Mechanical properties of brazed joints having an overlap of 12.7 mm (0.5 inch) are listed in Table IVA, while mechanical properties of brazed joints having an overlap of 6.35 mm (0.25 inch) are set forth in Table IVB.

TABLE IVA

Alloy	Shear Strength MPa (Psi)	Tensile Strength MPa (Psi)	Area of Failure
BCuP-5	44 (6,320)	174 (25,280)	Joint
BAg-1	46 (6,660)	184 (26,640)	Joint
BAg-2	43 (6,240)	172 (24,960)	Joint
Sample 1	51 (7,450)	208 (30,160)	Base Metal
Sample 2	41 (5,960)	164 (23,840)	Joint
Sample 3	53 (7,700)	212 (30,800)	Base Metal
Sample 4	52 (7,500)	207 (30,000)	Base Metal
Sample 5	44 (6,440)	178 (25,760)	Joint
Sample 6	52 (7,540)	208 (30,160)	Joint
Sample 7	51 (7,460)	206 (29,840)	Base Metal
Sample 11	48 (6,920)	198 (28,680)	Base Metal

TABLE IVB

Alloy	Shear Str ngth MPa (Psi)	T nsile Strength MPa (Psi)	Area of Failure
BCuP-5	93 (13,440)	185 (26,880)	Joint
BAg-1	72 (10,440)	144 (20,880)	Joint
BAg-2	62 (9,040)	125 (18,080)	Joint
Sample 1	81 (11,740)	162 (23,480)	Joint
Sample 2	71 (10,320)	142 (20,640)	Joint
Sample 3	102 (14,740)	203 (29,480)	Base Metal
Sample 4	77 (11,220)	155 (22,440)	Joint
Sample 5	68 (9,880)	136 (19,760)	Joint
Sample 6	87 (12,600)	174 (25,200)	Joint
Sample 7	94 (13,600)	188 (27,200)	Joint
Sample 11	65 (9,360)	129 (18,720)	Joint
Sample 13	93 (13,440)	185 (26,880)	Base Metal

Analyzes of the strength data indicated that at both 12.7 mm (0.5 inch) and 635 mm (0.25 inch) overlaps, alloys of the present invention exhibited comparable or superior strength to those of BCuP-5, BAg-1 and BAg-2 filler metals. The failure of the brazement in the base metal indicated a brazed joint stronger than the base metal.

Unnotched impact test specimens were prepared according to the following procedure. Copper blanks of dimensions 10 mm wide by 10 mm thick by 20 mm in length were used as the base metal. Ribbons of selected compositions, taken from the samples of Table I, having dimensions of about 25.4 m thick and 6.35 mm wide were used as the filler metal. Specimens were degreased in acetone and rinsed in alcohol prior to assembly. The foil filler metal was placed between the mating surfaces of the copper blanks. The joint assemblies were of the butt type where the foil thickness served as the clearance between the copper blanks. The assemblies were tack welded at the joint edges by laser welding. Specimens were furnace brazed at a temperature of 100°C over the liquidus in a nitrogen atmosphere at a pressure of 1 torr (133 P_a). After brazing, the samples were ground to

8.941 mm wide by 8.941 mm thick by 40 mm in length.

For comparative purposes, identical joints were prepared using 25.4 m thick BCuP-5 foil.

Test specimens were supported as beams in the vertical position. The test load was applied by the impact of a heavy, swinging pendulum striking the midspan of the specimen, i.e. at the joint.

Results of the unnotched impact testing are given in Table V below.

Alloy	Impact N-M	Energy to Failure (ft. - lbs.)
Sample 1	2.03	(1.50)
Sample 3	2.71	(2.00)
Sample 6	2.44	(1.80)
Sample 13	14.91	(11.0)
BCuP-5	2.51	(1.85)

Analysis of unnotched impact test data indicated that alloys of the present invention are equal or superior to that of BCuP-5. In particular, Sample 13 exhibits mechanical properties markedly superior to that of BCuP-5.

Having thus described the invention in rather full detail, it will be understood that such detail need not be strictly adhered to but that various changes and modifications may suggest themselves to one skilled in the art, all falling within the scope of the present invention as defined by the subjoined claims.

What is claim d is:

1. A metal alloy having a composition consisting essentially of 5 to 52 atom percent nickel, 2 to 10 atom percent tin and 10 to 15 atom percent phosphorus, the balance being copper and incidental impurities and the total of copper, nickel and tin ranging from about 85 to 90 atom percent.

2. A metal alloy composition as recited in claim 1, which has at least about 50% glassy structure.

3. A metal alloy composition as recited in claim 1, which has at least partially glassy structure.'

4. A homogeneous brazing foil having a composition consisting essentially of 10 to 52 atom percent nickel, 2 to 10 atom percent tin and 5 to 15 atom percent phosphorus, the balance being copper and incidental impurities and the total of copper, nickel and tin ranging from about 85 to 90 atom percent.

5. A homogeneous brazing foil having a composition consisting essentially of 5 to 15 atom percent nickel, 2 to 5 atom percent tin and 10 to 15 atom percent phosphorus, the balance being copper and incidental impurities.

6. A brazing foil as recited in claim 4, said foil having a thickness ranging from about 0.00254 to 0.00635 cm.

7. A brazing foil as recited in claim 4, said foil being ductile and having at least partially glassy structure.

8. A process for fabricating homogeneous ductile foil having a composition consisting essentially of 5 to 52 atom percent nickel, 2 to 10 atom percent tin and 10 to 15 atom percent phosphorus, the balance being copper and incidential impurities and the total of copper, nickel and phosphorus ranging from about 85 to 90 atom percent, which process comprises forming a melt of the composition and quenching the melt on a moving chill surface at a rate of at least about 10^5°C/sec.

9. A process for joining together two or more m tal parts which comprises:

(a) interposing a filler metal between the metal parts to form an assembly, the filler metal having a melting point less than that of any of the parts;

(b) heating the assembly to at least the melting temperature of the filler metal; and

(c) cooling the assembly; wherein the improvement comprises employing, as the filler metal, a homogeneous copper based foil having a composition consisting essentially of 5 to 52 atom percent nickel, 2 to 10 atom percent tin and 10 to 15 atom percent phosphorus, the balance being copper and incidental impurities and the total of copper, nickel and tin ranging from about 85 to 90 atom percent.

10. The process of claim 9 in which the ductile filler metal foil has a composition consisting essentially of 5 to 15 atom percent nickel, 2 to 5 atom percent tin and 10 to 15 atom percent phosphorus, the balance being copper and incidental impurities.

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Application number

European Patent Office

EUROPEAN SEARCH REPORT

EP 83 10 8759

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
X,Y	GB-A- 288 947 (G. REGNAC-PAILLE) * Claim 2 *	1	B 23 K 35/30 C 22 C 9/00 C 22 C 1/00

Y	EP-A-0 010 866 (ALLIED CHEMICAL) * Whole document *	1-10	

A,D	US-A-3 856 513 (H.S. CHEN et al.)		

A	GB-A-1 206 380 (EUTECTIC)		

A	US-A-3 392 017 (J.F. QUAAS et al.)		**TECHNICAL FIELDS SEARCHED (Int. Cl. 3)**

A	US-A-2 235 634 (F.R. HENSEL et al.)		B 23 K C 22 C

A	DE-A-2 241 342 (METALLGESELLSCHAFT)		

A	US-A-4 006 838 (R.S. BAUMANN et al.)		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12-12-1983	MOLLET G.H.J.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alon
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A : technological background
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